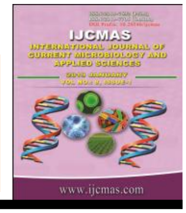
Int.J.Curr.Microbiol.App.Sci (2019) *8*(1): 1906-1911

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 01 (2019)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2019.801.200

Effect of Elevated CO_2 and Temperature on Growth of Rice Crop

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A B S T R A C T

Anthropogenic activities in few decades past have increased the concentration of the atmospheric greenhouse gases (GHGs) which leads to climate change. This changing climate will certainly have impact on agricultural production. A study was carried out during the *kharif* season of year 2017 inside the open top chamber (OTCs) in IARI farm, New Delhi to quantify the interactive effect of elevated CO_2 and temperature on growth of rice crop. Rice crop was grown in crates under two different CO_2 levels: ambient (400 ppm) and elevated (550±25 ppm) and with two temperature levels: ambient and elevated (+2°C). Growth of rice increased in elevated CO_2 treatment while it decreased under high temperature condition. This was observed in terms of changes in tiller number, straw weight and root weight of the crop. Straw weight of rice reduced from 44.7 g hill^{-1} to 52.1 g hill^{-1}in high temperature treatment. But increase in CO_2 concentration significantly increased straw weight of the crop. The study showed that increased CO_2 concentration was able to compensate the loss due to enhance growth of rice crop under high CO_2 condition.

Keywords

Elevated CO_2, High temperature, Rice, Crop growth

Article Info

Accepted:
12 December 2018
Available Online:
10 January 2019

Introduction

Since 1750, concentration of atmospheric CO_2 has increased from 278 ppm (Pearson and Palmer, 2000) to currently 400 ppm (IPCC, 2014). The atmospheric CO_2 concentration during 2002 to 2011 has increased at an average rate of 2.0 ± 0.1 ppm year^{-1}.

Changing climate will certainly have impact on agricultural production. Several researchers have reported that growth and yield of crops will be adversely affected due to increased atmospheric temperature (Zacharias *et al.*, 2010; Singh *et al.*, 2013). Although elevated temperature will harmfully affect crops, but increased CO_2 concentration can have certain positive impacts on crop growth and productivity. There are reports that, increase in atmospheric CO_2 concentration will increase the potential production of C3 crops at higher latitudes (Taylor *et al.*, 2018).

Rice (*Oryza sativa* L.) is an important food crop with half of world's population relying on rice every day (Maclean *et al.,* 2002). It is also the staple food across Asia where around half of the world's poorest people live and is becoming increasingly important in Africa and Latin America. Horie *et al.,* (2000) showed that an average increase in rice yield was about 30% with doubling of CO_2 concentration. Different studies on rice also showed that elevated CO_2 generally increased tiller number, photosynthesis, plant biomass and grain yield (Kobayashi *et al.,* 1999; Sakai *et al.,* 2001; Chakrabarti *et al.,*, 2012).

Although elevated CO_2 concentration has certain positive impacts on the crop but increased temperature will harmfully affect crop growth and productivity. Elevated temperature causes reduction in total dry matter, tiller mortality, reduced number of panicles, decline in number of grains per panicle, floret sterility, and grain weight thus overall reducing the yield of rice crop (Zacharias *et al.,* 2010). Raj *et al.,* (2016) also reported that high temperature stress of 3.9ºC significantly reduced grain and biomass yield of rice. Increase in daily mean temperature from 28°C to 32°C, significantly reduced total dry weight, root dry weight, root length, leaf area and specific leaf area of rice crop (Rankoth and De Costa, 2013). Rise in temperature at vegetative stage and early grain filling stage of various rice varieties showed lower photosynthesis rate in the crop (Cao *et al.,* 2009).

Although some work has been reported on effect of elevated CO_2 and temperature on rice but the interactive effect of elevated CO_2 and high temperature on rice is less reported especially under tropical condition. It is therefore important to study the response of rice as influenced by elevated CO_2 and temperature. Hence the following study was undertaken to study the impact of elevated CO_2 and temperature on growth of rice crop.

Materials and Methods

Study site

The study was conducted during the *kharif* season of year 2017 inside the Open Top Chamber (OTC) at ICAR-Indian Agriculture Research Institute (IARI), New Delhi, India. The climate of the area is semi-arid and subtropical with mean annual maximum and minimum temperature of 35°C and 18°C respectively. Both ambient (400ppm) and elevated CO_2 concentrations (550 ± 25ppm) were maintained inside the OTCs (Table 1). Elevated temperature was maintained by partially covering the upper portion of the OTC. Daily maximum and minimum temperature was recorded for the entire crop growth period using digital thermometer kept within the OTCs.

Crop management

Rice crop (variety Pusa basmati 1509) was grown in crates inside the OTCs. Recommended dose of nitrogen was applied in 3 splits i.e. half dose as basal and remaining half in two equal splits at tillering and flowering stage. Phosphorus and potassium were applied during transplanting of the crop. Plant samples were collected at harvesting stage and dry weight of straw and root were recorded. Growth parameters like plant height and no of tillers were also recorded. Statistical analysis of the data was done using SAS software. Factorial CRD design was followed.

Results and Discussion

Temperature gradient inside the open top chambers

Daily mean temperature was calculated from daily maximum and minimum temperature and then seasonal mean temperature inside all the OTCs was calculated. Temperature inside the partially covered OTC (elevated temperature treatment) was higher than chamber control OTC (elevated CO_2 treatment) by 2ºC (Fig. 1).

Plant height

Height of the rice plant was not affected by elevated CO_2 as well as high temperature. Plant height varied from 80.7 cm to 88.3cm in different treatments (Fig. 2).

Number of tillers

Increased CO_2 concentration significantly increased tiller number in rice plants. In chamber control treatment tiller number was 13.5 which increased to 16.1 in elevated CO_2 and chamber control temperature treatment (Fig. 3).

Table.1 Description of treatment combinations

Treatments	Description
OTC 1	Ambient CO_2 + Chamber control Temperature
OTC 2	Ambient CO_2+ Elevated Temperature
OTC 3	Elevated CO_2 + Ambient Temperature
OTC 4	Elevated CO_2 + Elevated Temperature

Fig.1 Mean seasonal temperature inside different OTCs

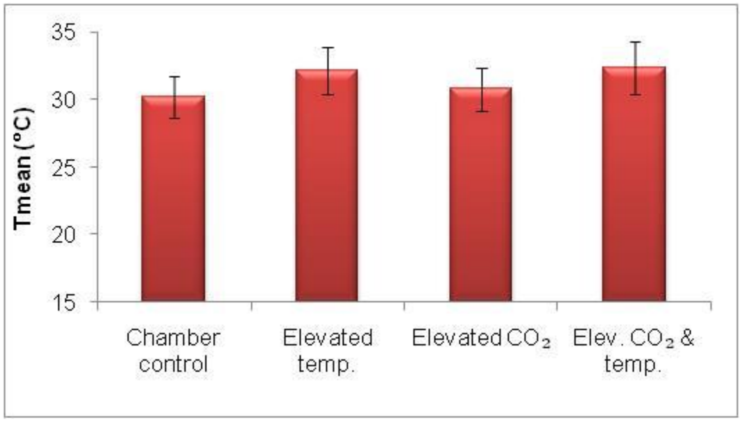


Fig.2 Effect of elevated CO_2 and temperature on plant height in rice

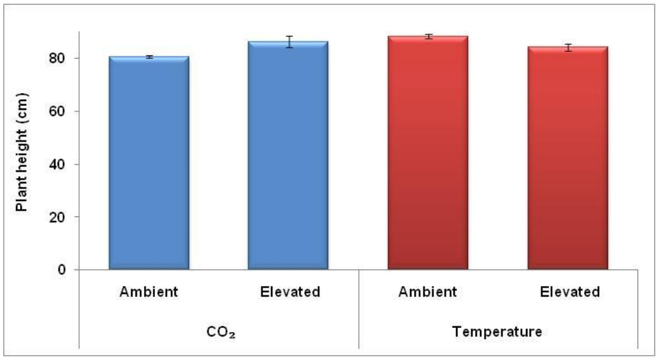


Fig.3 Effect of elevated CO_2 and temperature on tiller number in rice

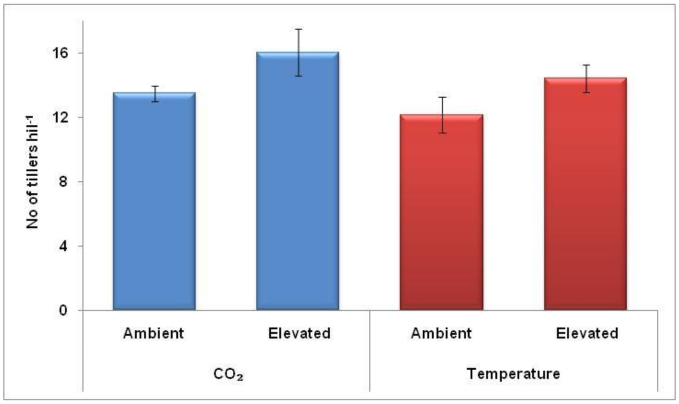


Fig.4 Effect of elevated CO_2 and temperature on straw weight in rice

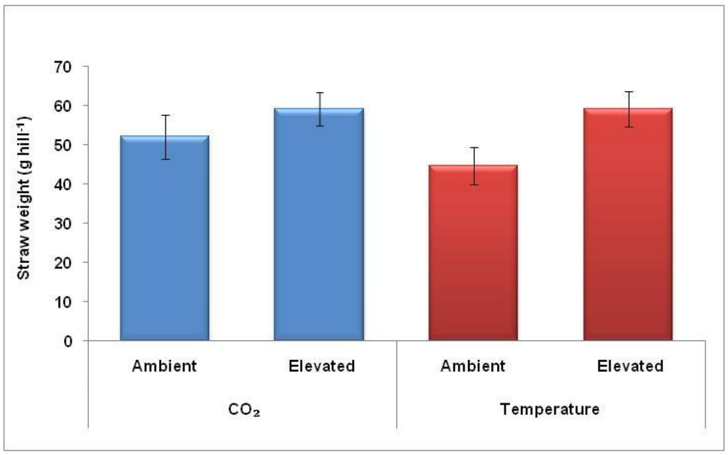
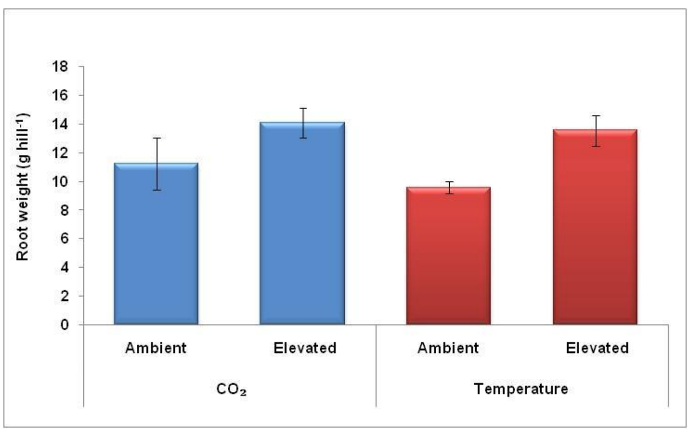


Fig.5 Effect of elevated CO_2 and temperature on root weight in rice



On the other hand increase in temperature reduced tiller number in rice. Tiller number decreased to 12.2 in elevated temperature and ambient CO_2 treatment. But elevated CO_2 along with high temperature recorded tiller number of 14.4. This showed that the negative effect of high temperature was compensated by elevated CO_2concentration. Increased photosynthesis rate of rice under elevated CO_2treatment resulted in accumulation of more biomass which was reflected in increased tiller numbers of the crop. Jitla *et al.,* (1997) also reported that at high CO_2 concentration there was 42% increase in tiller number in rice. Study conducted by Zacharias *et al.,* (2010) showed that high temperature induced tiller mortality in rice crop.

Straw weight

Rise in temperature led to reduced growth of the crop. Straw weight of rice reduced from 44.7 g $hill^{-1}$ to 52.1 g $hill^{-1}$in high temperature treatment under ambient CO_2 concentration (Fig. 4). But increase in CO_2 concentration significantly increased straw weight of the crop. Elevated CO_2 level along with high temperature was able to compensate the loss of temperature rise due to the CO_2 fertilization effect. In elevated CO_2 plus elevated temperature treatment straw weight was 59.2 g $hill^{-1}$. Singh *et al.*, (2013) also indicated that elevated CO_2 could alleviate the negative impact of high temperature but the effect is crop and region specific.

Root weight

Root weight of rice increased in elevated CO_2 treatment while high temperature caused reduced root weight of the crop. Root weight reduced from 11.2 to 9.6g $hill^{-1}$ in high temperature treatment (Fig. 5). In elevated CO_2 plus elevated temperature treatment root weight was 13.5 g $hill^{-1}$. Earlier studies also showed that increased root growth contributes to higher root biomass and root dry weight under elevated CO_2 condition (Rogers *et al.*, 1994, 1996).

In conclusion, results from the experiment showed that growth of rice crop reduced under high temperature treatment which was observed in terms of reduced tiller number, straw weight and root weight of rice plants. But increased CO_2 concentration was able to compensate the loss due to enhance growth of the crop under high CO_2 condition.

Acknowledgements

The authors are thankful to the PG School and Director of ICAR-IARI for providing the fellowship towards pursuing M.Sc. programme.

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How to cite this article:

Partha Pratim Maity, B. Chakrabarti, A. Bhatia, T.J. Purakayastha, Namita Das Saha, R.S. Jatav, A. Sharma, A Bhowmik, V. Kumar and Chakraborty, D. 2019. Effect of Elevated CO_2 and Temperature on Growth of Rice Crop. *Int.J.Curr.Microbiol.App.Sci.* 8(01): 1906-1911.
doi: https://doi.org/10.20546/ijcmas.2019.801.200